The Thesis Committee for Lauren Brooke Schwartz
Certifies that this is the approved version of the following thesis:

Identification of Sentence Emotional Content in Individuals with Traumatic Brain Injury

APPROVED BY
SUPERVISING COMMITTEE:

Supervisor: ______________________________
Thomas Marquardt

____
Harvey Sussman

Identification of Sentence Emotional Content in Individuals with Traumatic Brain Injury

by

Lauren Brooke Schwartz, B.A.; B.S.

Thesis

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Master of Arts

The University of Texas at Austin

May 2013

Acknowledgements

I would like to thank my parents, Mark and Arlene Schwartz, for their love and support; my brother, David Schwartz, for his unwavering conviction; the Mary Lee Foundation for their bountiful cooperation; Dr. Harvey Sussman for his vital insight; and Dr. Thomas Marquardt who has been an endless source of guidance, wisdom, and mentorship.

Abstract

Identification of Sentence Emotional Content in Individuals with Traumatic Brain Injury

Lauren Brooke Schwartz, M.A.

The University of Texas at Austin, 2013

Supervisor: Thomas Marquardt

In the following study, a lexical emotion recognition test via written stimuli was administered to 10 (8 male and 2 female) brain injured participants. Performance of brain injured individuals was compared to 30 non brain injured adults. A two way analysis of variance (groups, conditions) revealed significant effects for groups, conditions, and the interaction of groups and conditions. Implications and significance of the present results for future research are discussed.

Table of Contents

List of Tables

List of Figures

INTRODUCTION

The introduction and increased use of incendiary explosive devices in military warfare, increasing rates of motor vehicle accidents, continued rates of infant and geriatric related falls, and the advent of new research investigating the consequences of repeated concussive injuries in sports related accidents is generating a need for improved services for traumatic brain injury. Traumatic brain injury results in a series of cognitive, physical, and behavioral deficits in both the short and long term. Two behavioral processes most affected are social pragmatics and emotion recognition. Social deficits due to impairment in emotion recognition often go undiagnosed and untreated because the affected individual is unaware of their deficits or the possibility of their existence. The ability to express and understand emotion is essential to human existence, allowing us to relate to others, communicate effectively, and generate innovative and novel concepts. How we perceive emotion contributes motivation to our actions, speech, and other such responses to external stimuli. Impairment in emotional processing inhibits the basic human need to connect with others.

In the following study, a lexical emotion recognition test via written stimuli was administered to 10 (8 male and 2 female) brain injured participants. Performance of brain injured individuals was compared to 30 non brain injured adults. A two way analysis of variance (groups, conditions) revealed significant effects for groups, conditions, and the interaction of groups and conditions. Implications and significance of the present results for future research are discussed.

Traumatic Brain Damage

Traumatic brain injury (TBI) is the result of sudden physical trauma or external forces acting on the skull or brain. Brain injuries are classified as either penetrating or non-penetrating depending on the presentation of the damage. Injuries in which the skull is fractured or perforated, meninges are torn or lacerated, or the damage extends to the brain tissue are classified as penetrating head injuries or open-head injuries. These injuries are usually a result of missile wounds or high velocity impacts to the head by sharp objects. Injuries in which brain damage occurs within an intact skull and meninges are classified as non-penetrating or closed-head injuries.

Brookshire (2007) described the different types of brain injury and resulting consequences. Non-penetrating head injuries are more common than penetrating head injuries and are usually caused by falls, motor-vehicle accidents, or low velocity impact by a blunt object. Non-penetration head injuries present as either acceleration-deceleration or nonacceleration. Acceleration-deceleration head injuries present when the head, set in motion by physical forces, stops abruptly or when the head, at rest but moveable, is rapidly accelerated. Depending on the location of the injury, acceleration-deceleration injuries can be classified further into linear acceleration injuries or angular acceleration injuries. Linear acceleration injuries occur when the external force striking the head passes through the central axis causing it to move in a linear direction. In a situation such as a fall, when the head accelerates, the brain remains in place and thus strikes the inside of the skull causing bruising and diffuse axonal injury at the point of impact. This impact causes the brain to move and accelerate in the opposite direction. When the head comes to a stop, the brain will stay in motion, causing an impact on the inside of the skull on the opposite side of the initial impact and further bruising and axonal injury. The injury at the initial point of impact is called the coup injury; the injury at the opposite point of impact is called the contrecoup injury. Angular acceleration injuries occur when the external force striking the head does not pass through the central axis, causing the head to rotate away from the point of impact. Non-acceleration injuries occur when a restrained head is impacted by an external moving object. The principal result of a non-acceleration injury is the impression it leaves on the skull. The object that causes the assault bends the bone of the skull inward, damaging both the meninges and the cortex. Additionally, non-acceleration injuries can result in a skull fracture which could increase the potential for cranial nerve damage and infection. Pang (1989) states that acceleration-deceleration injuries are twenty times more devastating than non-acceleration injuries.

Penetrating head injuries, whether by high velocity or low velocity missiles, cause diffuse damage to the brain tissue and internal bleeding. The threat of infection increases as the bullet carries foreign material such as dirt, hair, and skull fragments into the brain tissue (Brookshire, 2007).

Finlayson & Grarner (1994) reported on the incidence rates of traumatic brain injury, finding that males are more likely than females to sustain a traumatic brain injury, especially in young adults. Men are more likely to engage in risky behavior, thus increasing their chances of sustaining a head injury. The ratio of men to women between 15 and 25 years old is 2 to 1 respectively. In persons under the age of 50, traumatic brain injury is the leading cause of neurologic debility, most often due to motor vehicle accidents. Toddlers and persons above the age of 75 are at an increased risk of brain injury as compared to the general population due to the possibility of sustaining a fall.

Evidence confirms that individuals with brain injury often experience impairment in cognitive processes such as executive functions. Executive functions are defined as complex, high level cognitive processes such as planning, organizing, judgment, and time management. Additionally, persons with TBI report deficits in attention and speed of information processing following their injury (Levin *et al.*, 1987).

Recent evidence suggests that individuals with TBI experience deficits in working memory (McDowell, Whyte, & D'Esposito, 1997). The amount of information that must be held in immediate storage in order to solve a particular problem is called the working memory load. Imaging techniques such as fMRI have been used in several studies to identify the networks in the brain that are associated with working memory (see D'Esposito *et al.*, 1998, for review). These studies found bilateral frontal and parietal activation associated with performance during working tasks (Smith & Jonides, 1998). Due to their location on the cortex, neural networks associated with working memory are vulnerable to external force and therefore susceptible to traumatic damage. Furthermore, a correlation exists between increased working memory processing load and increased activation of established neural networks associated with working memory (Braver *et al.*, 1997; Cohen *et al.*, 1997).

McDowell et al. (1997) discussed the role of the central executive system in individuals who suffered from a severe traumatic brain injury. Using a dual-task paradigm, 25 individuals (at various stages of recovery) and a control group of age-matched individuals participated in a simple visual reaction time task. Experimental data were obtained to test working memory function using oral digit span and a delayed spatial response task. Executive function was assessed using various standardized neuropsychological tests. Results indicated that TBI patients had slower reaction times on the primary task when performed alone and an even greater decrease in performance during dual-task conditions. TBI patients demonstrated greater deficits in executive functioning than the control subjects. The researchers concluded that TBI patients have working memory impairment, due to dysfunction of the central executive system.

McAllister,Sparling, Flashman, Guerin, Mamourian, and Saykin (2001) demonstrated that mild TBI patients demonstrated a different pattern of allocation of processing resources associated with a high processing load task compared to healthy controls. The proposed reason for this pattern suggest unimpaired populations have a larger pool of processing reserves to draw upon, utilizing other regions of the brain in addition to the regions associated with working memory, whereas mild TBI patients have far fewer additional reserves to draw from (McAllister et al., 2001). Deficits in working memory could lead to impaired ability to interpret emotional stimuli while simultaneously completing a reading task.

Persons with traumatic brain injury (TBI) experience a gamut of emotional and social behavior changes as well including emotional instability, poor social judgment, and loss of inhibition are among the most common and debilitating of these consequences (Kendall & Terry, 1996; Levin, 1995; Prigatano, 1992). As a result, many patients fail to return to work or maintain meaningful social relationships (Brooks, McKinlay, Symington, Beattie, & Campsie, 1987; Malia, Powell, & Torode, 1995).

A possible cause of social isolation and behavioral dysfunction following a TBI is the inability to recognize emotional cues and respond appropriately during social interactions (Milders, 2003). Difficulty in identifying emotion is known as alexithymia- an impairment in the ability to identify emotion, describe emotion, and utilize theory of mind (Larsen, 2003). These emotion processing deficits have strong repercussions on social functioning as communication is necessary to build social relationships. For example, persons with TBI suffer from reduced quality-of-life, increased anxiety, and depression (Dijkers, 2004).

Emotional Processing for Neurotypical Individuals

The consequential damage of a traumatic brain injury is diffuse, often affecting both the right hemisphere and the left hemisphere, the former of which regulates emotional processing while the latter regulates lexical processing. Often the diffuse axonal damage from a traumatic brain injury overlaps with limbic and associated structures that are responsible for emotion processing. The limbic system regulates the experience of emotion but the right hemisphere regulates the expression of emotion as well as the ability to appreciate the emotions expressed by others (Tucker & Frederick, 1989).

Thus, emotional processing is largely lateralized in the right hemisphere, however, there are many different neural mechanisms in the brain that are additionally affiliated with these cognitive processes including the prefrontal lobe, frontal lobe, temporal lobe, parietal lobe, and amygdala. Two theories have been developed to explain the cognitive processes that underlie emotional processing- Right Hemisphere Dominance Model theory and Valence Model theory- will be described.

The right hemisphere dominance theory suggests that the right hemisphere is specialized to process emotional stimuli and regulates emotional experience, expression, and perception (Borod, Koff, & Caron, 1983). This theory is supported by evidence from behavioral studies examining three different channels by which emotion is expressed and perceived – facial, prosodic, and lexical affect. Research has found that patients with right hemisphere damage have deficits in recognition of emotional facial expression (Spell & Frank, 2000), displaying facial expression (Borod, 1985), recognition of emotional intonation (Ross & Mesulam, 1979), and identification of emotion in written form (Borod, Andelman, Obler, Tweedy, & Welkowitz, 1992). Right hemisphere dominance theory garners additional support from studies that examined emotional processing in in healthy participants, discovering that the left side of the face is emotionally more expressive (Sackeim et al., 1978); emotional prosody is more easily recognized when presented to the left ear (Erhan et al., 1998), and stimuli presented in the left visual field are judged as more emotional (Levine & Levy, 1986). Due to pyramidal decussation, results from the studies of Sackeim et al., (1978); Erhan et al., (1998); and Levine and Levy, (1986) support the proposal that the right hemisphere is largely responsible for processing emotional stimuli.

The second hypothesis, Valence theory, posits that the perception of emotion is processed in both hemispheres depending on the type of emotion- positive emotions primarily within the left hemisphere and negative emotions within the right (Demaree, Everhart, Youngstrom, & Harrison, 2005; Wager, Phan, Liberzon, & Taylor, 2003). A number of studies have published data in support of this theory, for example, Adolphs et al. (1996) found that patients with right hemisphere damage have an increased tendency to experience greater deficits perceiving negative versus positive emotion while the perception of happy affective faces is typically unaffected (see Adolphs et al., 1996).

Deficits in Emotion Recognition for Individuals with TBI

Diffuse axonal damage, a hallmark of traumatic brain injury, typically affects both hemispheres. Therefore, impairments of cognitive functioning associated with the right hemisphere are expected. Emotional processing deficits due to damage of the right hemisphere are well documented and research suggests that individuals with traumatic brain injury demonstrate a decreased ability to accurately recognize emotional tone expressed in the faces of others, recognize emotional tone in the voices of others, and a decreased ability to express themselves effectively using an appropriate facial expression or affective prosody, also known as flat affect (Green et al., 2004; Jackson & Moffat, 1987; Milders et al., 2003; Prigatano & Pribram, 1982; Spell & Frank, 2000; Marquardt et al., 2001; McDonald & Pearce, 1996; McDonald et al., 2003; McDonald & Flanagan, 2004, McDonald & Saunders, 2005). Deficits in these areas may signify a failure to appreciate emotional implications of changes in prosody, a failure to appreciate emotional implications of changes in facial expression, a failure to utilize theory of mind, or a failure to infer the emotional tone of various situations (Brookshire, 2007).

Research reveals that individuals with damage to the right hemisphere have increased difficulty in generating predictive inferences, suggesting that the right hemisphere (RH) plays an important role during related tasks (Beeman, 1993; Brownell, Potter, Bihrle, & Gardner, 1986). Compared to healthy age matched peers, individuals with brain damage in the right hemisphere homologous to Wernicke's area identified the correct answer to questions pertaining to explicitly stated information with comparable accuracy. In contrast, these same individuals demonstrated difficulty responding correctly to true/false questions about implied information (Beeman, 1993; Brownell, et al., 1986). Severe damage to the right hemisphere could impair the ability to make correct inferences regarding emotional stimuli.

Individuals with right hemisphere brain damage experience decreased ability to draw inferences due to the fact that the right hemisphere codes semantic information necessary for discourse. This information is spread out in overlapping, diffuse networks and damage to this network might cause a disruption of the flow of information through these semantic networks.

For example, an individual may be able to recall the denotation of a word but will not be able to recall other semantic information necessary for making relationships between the word and other concepts in order to make coherent inferences about a given piece of information (Beeman, 1993).

Individual differences in working memory capacity can affect the prospect of correctly drawing predictive inferences (Whitney, Ritchie, & Clark, 1991). In a study by St. George, Mannes, & Hoffman (1997), evoked response potentials (ERP) were used to record neural activity and it was determined that individuals with an increased working memory capacity were more adept at making predictive inferences than individuals with, on average, lower working memory capacities (St. George et al., 1997). Impairment in inferential processing could decrease the efficiency of recognizing emotion in external stimuli.

Individuals who have sustained a brain injury characteristically demonstrate more errors than those who are non-brain injured on tests of emotion recognition of facial expression, particularly for negative emotions (Blonder, Bowers, & Heilman, 1991). A majority of studies examining this area of research rely on still photographs of actors intending to convey a facial expression of a certain emotion (Prigatono & Pribram, 1982; McDonald & Saunders, 2005; Green, Turner, Thompson, 2004; Spell & Frank; 2000). The participants are then required to match these photographs with a corresponding emotional label. Still photographs remain limited in terms of context and movement clues, limiting individuals with brain injury who exhibit difficulty analyzing and integrating visuospatial information. Thus, controversy remains regarding the source of errors in emotion recognition in facial expression by individuals with brain injury, corresponding either to a failure in interpretation of emotional expression or a fundamental impairment in the analysis and incorporation of visuospatial information (Myers, 1999).

Similar to facial expression, individuals who are brain injured characteristically demonstrate more errors than those who are non-brain injured on tests of emotion recognition of spoken sentences (Blonder, Bowers, & Heilman, 1991, Marquardt et al., 2001; McDonald & Pearce, 1996; Milders et al., 2003; Spell & Frank, 2000). Studies seeking to understand this deficit suggest that individuals with brain injury experience a failure to accurately interpret changes in pitch and intonation in vocal prosody. Other research suggest individuals with brain injury have an underlying impairment in their ability to accurately perceive, discriminate, and process the acoustic information related to pitch and intonation patterns (Brookshire, 2007). In their study, Dimoska, McDonald, Pell, Tate, & James (2010) found that individuals rely more heavily on semantic information rather than prosodic information coded in spoken sentences to determine emotion. Thus, more research is needed to examine patterns of emotion recognition coded in linguistic information in individuals with traumatic brain injury.

Studies suggest that the form of media that stimuli are presented on may enlist different neurological systems (McDonald & Saunders, 2005). Though the neurological correlates in the brain that process affective prosody and facial expression overlap, persons with focal lesion damage do not consistently present with difficulties in both face and voice expression, an indication of separate processing (Hornak, Rolls, & Wade, 1996). Likewise, Adolphs, Tranel, & Damasio (2003) have argued that dynamic images and static images conveying emotion are processed in different neurological systems.

Studies seeking to understand the response pattern persons with TBI tend to follow when selecting appropriate emotion intensity scores suggest that they tend to apply a liberal attribution bias, meaning persons with TBI will tend to select a high rating of intensity regardless of whether the emotion label is correct or not. A liberal bias signifies that TBI patients give high ratings to correct label in addition to high ratings to incorrect labels (Callahan, Ueda, Daisuke, & Plamondon, 2011). Previous data describing patterns of deficits in emotional recognition for individuals with TBI provides the foundation for which future research, including this study, may aim to enhance.

Emotion Recognition in Lexical Stimuli for Individuals with TBI

One aspect of deficits in emotion recognition that has received relatively little attention is the lexical (i.e. speech content) domain of emotional communication. Relatively little research has adressed the complex hemispheric processes that underlie the role that language plays in the communication of emotion. Wechsler (1973) reported that right brain-damaged individuals showed greater deficits in recall of emotionally laden text in comparison to left brain-damaged individuals (LBDs). Borod and his colleagues (1985) examined the three different channels of emotion (facial, prosodic, and lexical) in individuals with both right and left brain damage and discovered that, when compared to the other population groups, right brain damaged individuals exhibited less appropriate oral expression of feelings. Borod et al. (1985) noted that their speech was more matter-of-fact than prosodic, and more descriptive than emotional. Borod et al. (1992) later examined the role of the lexical channel in perceptual emotional processing for individuals with right and left brain damage. Participants were required to complete dual emotional and nonemotional (cognitive) tasks of word identification, sentence identification and word discrimination. Results from this study concluded that the right brain damaged individuals revealed a decrease in performance accuracy on the word identification task as compared to the left brain damaged individuals and a the control group of healthy individuals. Furthermore, the right brain damaged participants showed an increase in performance discrepancy on the word identification task and the word discrimination task as compared to the other population groups (Borod, 1992).

Assessment Tools for Affective Lexical Stimuli

There is increasing interest in developing assessment tools for Alexithymia in persons with TBI (Ben-David, Lieshout, & Leszcz, 2011). The first step in developing a valid assessment tool for emotion recognition in affective lexical stimuli is to create a well-controlled set of verbal stimuli that can be used in a spoken or written context.

Russ, Gur, & Bilker (2008) completed the first study that established a list of sentences conveying distinct emotional information based on lexical content. Russ et al. (2008) stressed the importance of dissociating prosody from sentence content to ensure the communicated emotion resulted directly from intonation rather than from the connotation of the involved lexical content. There are two ways to achieve this goal. After confirming sentence content as neutral, the expressed emotional prosody in the stimuli is varied. Alternatively, emotionally charged content is initially presented using similar emotional prosody; then later the expressed prosody is replaced by a dissimilar emotion to use as a comparison (Russ et al., 2008).

Russ et al. (2008) asked participants to read sentences with content that suggested happiness, sadness, anger, fear, or neutrality and rate how well each sentence conveyed each emotion. Statistical analysis reduced the list to affective sentences that had high agreement and neutral sentences that had low agreement. The list of sentences in the Russ et al. (2008) study does not meet testing standards for emotional processing assessment tools for persons with TBI.

First, the group of raters used was comparatively small (n =12). Secondly, the sentences were not matched on frequency of usage or on phonologic neighborhood density (Russ et al., 2008). Emotional content words that occur more frequently in the lexicon are easier to identify (Bruce, Harman, & Turner, 2007). That is, some words have a higher chance of occurring in daily usage than others. Ease of word identification increases as probability of daily usage increases. Thus, word frequency could potentially cause a difference in the identification of emotions between categories should sentences in one emotional category have a higher lexical frequency than sentences in other categories (Ben-David et al., 2011). The ability to identify spoken words decreases as neighborhood density increases and thus could potentially have an effect on the identification of emotion in speech (Ziegler, Muneaux, & Grainger, 2003). These linguistic properties must be taken into account in order to avoid an unintentional negative affect on cognitive processing.

Ben-David et al. (2011) developed a list of sentences with controlled linguistic properties that accurately reflect various emotions. Forty-eight young adults rated emotional content in a set of 125 lexical sentences in five affective categories (Anger, Fear, Happiness, Sadness, and Neutral) that were matched on frequency of usage in the English language and on phonologic neighborhood density. Using a set of strict criteria to narrow down the results, 50 sentences, considered either strongly associated with one type of emotion or strongly associated with no emotion, were identified. Ben-David et al. (2011) hypothesized that “these sets form, to date, the most optimized lexical stimuli to test the identification of emotion in both visually presented and spoken language, specifically with patient populations with acquired brain injury.” Though researchers now have this set of validated lexical stimuli at their disposal, to our knowledge, the sentences have not yet been tested on the population they were intended to assess.

Purpose

The objective of this study is threefold. In addition to exploring the sensitivity of the emotional assessment stimuli to identify sequelae of mild traumatic brain injury (TBI) developed by Ben David in his 2010 study, this study aims to determine if there are significant differences in recognition of emotionally loaded lexical stimuli between individuals with traumatic brain injury (TBI) and individuals without brain damage (NBD) with regard to total error and type of error. Recognition abilities in individuals with TBI will be contrasted with recognition abilities of individuals with no history of brain damage, referred to as non-brain damaged (NBD) individuals. Based on previous research by Green et al., 2004; Jackson & Moffat, 1987; Milders et al., 2003; Prigatano & Pribram, 1982; Spell & Frank, 2000; Marquardt et al., 2001; McDonald & Pearce, 1996; McDonald et al., 2003; McDonald & Flanagan, 2004, McDonald & Saunders, 2005; Borod et al., 1985; and Borod et al., 1992, it is predicted that individuals with brain injury will make more total errors than non-brain injured individuals. According to research based on Adolphs et al., 1996, it is predicted that both groups will demonstrate less errors for the happy affect. Additionally, it is predicted that individuals with brain injury will demonstrate the highest number of errors for the anger affect and the second highest number of errors for the neutral affect. Results from this study may provide a basis for future intervention targeting explicit teaching of emotional words and language and can lead to improved diagnosis of emotional processing disorders.

METHOD

Participants

Ten individuals with brain injury and 29 non-brain injured individuals participated in this study. The experimental group consisted of 8 male and 2 female brain injured individuals ranging between 27 and 62 years of age (mean=40 years). Self-reports confirmed a diagnosis of mild to moderate-severe brain damage. Participants were at least 6 months post onset of injury (mean=13 years). Brain injured participants resided in an extended care facility for individuals with TBI and were recruited through a previous study conducted by the University of Texas at Austin. Scales of Cognitive Ability for Traumatic Brain Injury (Adamovich & Henderson, 1992) full scale scores, obtained post-injury, were available for all 10 subjects (See Table 2). Additionally, participants were native English speakers and demonstrated adequate visual acuity and reading capabilities that were functional for this task. No individuals with evidence of visual neglect were included in the study. Individuals in the unimpaired group consisted of 13 male and 16 female non brain injured individuals ranging between 19- 57 years of age (mean=25 years). These individuals were native English speakers with adequate visual acuity and reading capabilities that were functional for this task.

Table 1. Age, time post injury, gender, and reading subtest results for TBI participants

Participant	Age (years)	Time Post Injury (years)	Gender	Reading Task	
				Sentence-Picture	Morpho-Syntax
1	39	1.33	M	10	9
2	60	18.16	M	10	8
3	39	8.58	M	9	9
4	62	37.75	M	10	7
5	43	28	M	10	10
6	35	8	M	9	10
7	45	6.5	M	10	10
8	29	13	M	9	8
9	29	12.5	F	9	9
10	27	4.4	F	10	9
MEAN	40.8	13.82		9.6	8.9

Table 2. SCATBI subtest scores for TBI participants

	Scales of Cognitive Ability for Traumatic Brain Injury (SCATBI)						
Participant	**Perc***	**Orie***	**Org***	**Reca***	**Reas***	**Total**	**Severity**
1	98	119	107	110	125	113	Borderline Normal
2	113	101	129	125	125	128	Average Normal
3	104	119	129	98	103	112	Mild
4	92	119	129	101	114	112	Mild
5	98	119	129	133	131	135	Average Normal
6	108	97	115	90	94	98	Mild
7	108	119	129	119	112	125	Borderline Normal
8	93	91	95	100	100	92	Moderate
9	104	119	129	98	117	120	Borderline Normal
10	98	101	119	100	97	101	Mild
Mean	101.43	106.71	120.71	105.14	108	109.71	

Table 3. Age and gender of neurotypical participants (n=29)

Participant	Age	Gender
1	24	F
2	56	F
3	57	F
4	24	F
5	24	F
6	21	F
7	24	F
8	20	F
9	22	F
10	22	F
11	20	F
12	27	F
13	20	F
14	20	F
15	22	F
16	22	F
17	55	M
18	23	M
19	24	M
20	24	M
21	23	M
22	21	M
23	22	M
24	22	M
25	19	M
26	21	M
27	22	M
28	20	M
29	26	M
MEAN	24.76923077	

Stimuli

The stimuli used for this experiment were derived from Ben-David et al. (2011). Ben-David et al. (2011) developed 50 lexical sentences that were considered strongly associated with an emotion or a neutral emotion. The sentences were assigned to five affective categories

(Anger, Fear, Happiness, Sadness, and Neutral) each containing 10 sentences. The stimuli were matched on frequency of usage in the English language and on phonologic neighborhood density. An additional set of 44 sentences using a more relaxed set of criteria also were published in Ben-David et al.'s (2011) study. These sentences were deemed "good representatives for these affective categories" (Ben-David et al., 2011). Five of these forty-four sentences served in the current study as practice sentences to orient participants to the task. The sentences were presented individually on a Microsoft Powerpoint presentation on a 15.6" HD widescreen display in size 32 font. Five different randomized trials were created using a VBA macro code. Each sentence is about 4-10 words in length. The participants responded to each sentence using a response sheet. The response sheet was a printed handout that displayed five pictograms representing each of the five affective categories. The pictogramss were simplistic in nature, constructed using features from the Shapes application on Microsoft Word. The handout was placed on the table directly in front of the participant.

Procedures

The participants were tested at the site of the independent living center where the participants resided. Each participant required one 30-45 minute session to complete the tasks. Prior to testing, a number of formal and informal assessment tools were used to evaluate performance level. The participants were assessed using the Scales of Cognitive Ability for Traumatic Brain Injury (Adamovich & Henderson, 1992) and the California Verbal Learning Test (Delis, Kramer, Kaplan, & Ober, 2000). Assessments included screenings for reading ability, visual acuity/visual neglect, and fine motor movement. In order to assess reading competence, participants were administered two subtests from the Reading Comprehension

Battery for Aphasia (LaPointe & Horner, 1998). These subtests included *Sentence Comprehension* and *Morpho-Syntactic Reading with Lexical Controls*. These subtests were conducted to detect the existence and degree of a reading impairment and were chosen based on their linguistic similarities to the stimuli used in the experimental task. Participants who achieved a raw score of 7 or more on each subtest were included in the study. Mean raw score for *Sentence Comprehension* was 9.6 and mean raw score for *Morpho-Syntactic Reading with Lexical Controls* was 8.9. Visual acuity and visual neglect were assessed using a scanning procedure that required the participant to recognize and identify letters on a printed handout similar to the font size of the task. The task required the participant to use visual scanning abilities to search for each letter. The handout contained nine letters arranged in three rows of three with equal space in between. These nine letters represented the nine quadrants of the visual space. Each subject was required to identify reliably (9/9 in random order) the letters represented by pointing in response to auditorally presented phrases (e.g. “Show me H”). A preliminary orientation was completed to determine whether the participants were able to differentiate the five emotional categories employed in the experiment. The administrator placed the response sheet containing the five pictograms on the table. Each subject was required to identify reliably (5/5 in random order) the emotions represented by pointing in response to auditorally presented phrases (e.g. “Show me sad”) before proceeding to the experimental task. Participants who could not respond reliably using an index finger were excluded from the study. Next, the computer monitor was placed at eye level approximately 1 meter from the subject. The task consisted of 55 slides on a single Powerpoint presentation. Each participant was randomly assigned to one of the five randomized task trials. The first five slides functioned as practice items with the purpose of orienting the participant to the task. Subjects were instructed to view each pretrial stimulus and indicate gesturally by pointing to the response form. If an incorrect answer was indicated, the subject was immediately provided with the correct answer before moving on to the next pretrial item. Subjects who met criterion performance levels on the preliminary screening and pretrial items were administered the experimental test conditions.

Each sentence stimuli was presented for 10 seconds in the center of the screen in black text. The participant was required to read the sentence and manually point to the corresponding pictogram on the response sheet placed on the table. If the participant could not identify a facial expression after five seconds had passed, the administrator advised the participant that only five seconds remained. For any given item, the probability of a correct response by random selection was 20%. The administrator was positioned behind the participant in order to record their responses. A correct response was defined as the selection of a pictogram that reflected the linguistically coded affect of the stimulus sentence. The raw scores were converted to percent correct scores for each subject, group, and condition.

RESULTS

The number of correct responses to the 10 stimulus sentences for each emotion condition was calculated for the neurotypical and TBI participants (See Table 4 and Table 5). Total mean scores reflected the minimal errors for the neurotypical participants ($X = 48.13$) in contrast to increased errors for the participants with TBI (40.70) (See Figure 1). Mean performance for the neurotypical participants varied from 9.13 (sad) to 9.96 (happy); for the TBI group from 9.8 (happy) to 6.6 (angry). A two way analysis of variance (groups, conditions) revealed significant effects for groups ($F = 33.32$; $p < .001$) , conditions ($F = 7.97$; $p < .001$) and the interaction of groups and conditions ($F = 3.42$; $p < .001$). The significant interaction was the result of minimal errors for the emotion conditions for neurotypical participants with differential effects of the sentences for the TBI participants. Post-hoc comparisons for conditions with Bonferroni corrections found significant differences between the conditions of happy and angry (p. = .001) and angry and neutral ($p = .016$). No other comparisons were significant. Pair wise comparisons of performance of the TBI participants on the sentences revealed significant differences ($p < .05$) between happy and fear, between angry and neutral, and between happy and angry.

In summary, the neurotypical participants produced significantly fewer errors than the TBI participants on the stimulus sentences, but a significant interaction resulted from the minimal errors on the sentences in contrast to differential effects of sentence emotion by the TBI participants. There were significant differences between the sentence conditions reflecting better performance on the happy and neutral sentences compared to the angry sentences. Comparisons of conditions for the TBI participants found differences between happy and neutral sentences and angry and neutral sentences.

Figure 1. Mean raw scores for TBI subjects and neurotypicals

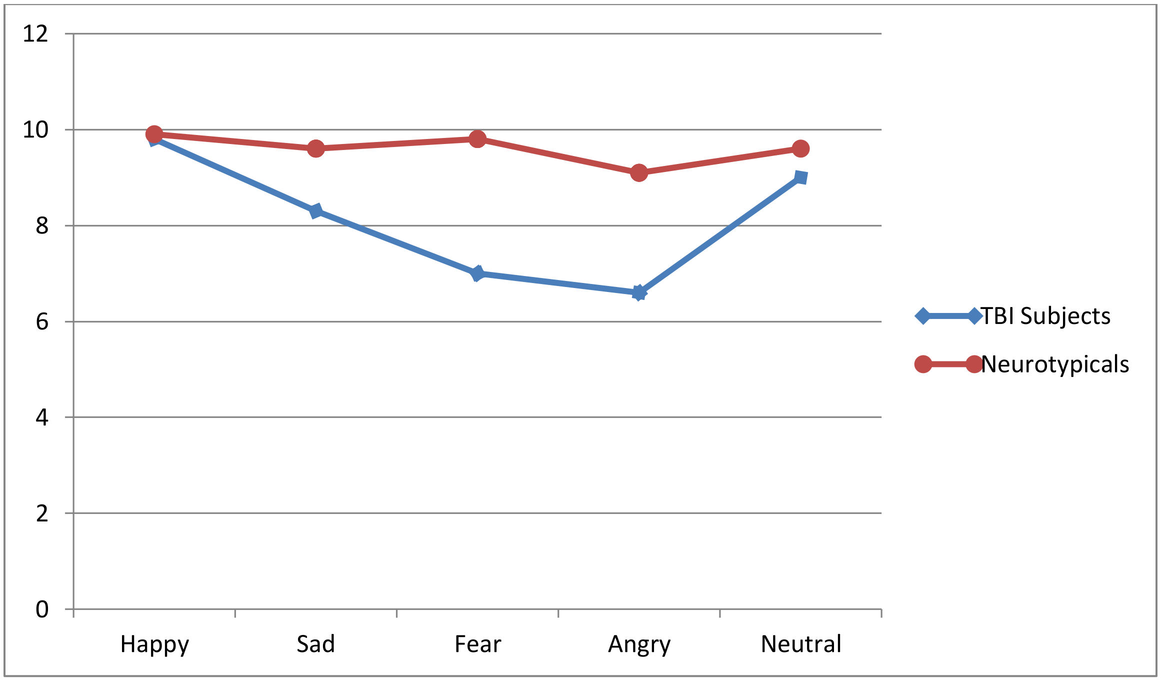


Table 4. Raw scores for TBI subjects

Participant	Happy	Sad	Fear	Angry	Neutral	Total
1	8	2	4	7	10	62
2	10	10	10	7	7	88
3	10	7	9	8	10	88
4	10	10	5	4	6	70
5	10	10	10	10	10	100
6	10	10	2	3	9	68
7	10	10	9	6	10	90
8	10	5	3	6	8	64
9	10	9	9	7	10	90
10	10	10	9	8	10	94
Mean	9.8	8.3	7	6.6	9	81.4

Table 5. Experimental task raw scores for neurotypical subjects

Participant	Happy	Sad	Fear	Angry	Neutral	Total
1	10	10	10	9	10	100
2	10	10	10	10	10	100
3	10	10	10	9	10	98
6	10	10	10	5	10	90
8	10	10	10	10	10	100
11	10	10	10	10	10	100
12	10	10	10	6	10	92
14	10	10	10	10	10	100
15	10	10	10	7	10	94
16	10	10	10	10	9	98
19	10	10	10	9	10	98
21	10	9	10	7	8	88
22	10	10	10	10	10	100
26	10	9	10	10	10	98
27	10	9	10	9	10	98
29	10	10	10	10	10	100
30	10	10	10	10	9	98
4	10	10	10	9	10	98
5	10	10	10	9	10	98
7	10	8	10	9	9	92
9	10	10	10	9	9	96
10	10	10	10	10	10	100
13	9	9	9	9	10	92
17	10	9	9	9	8	90
18	10	9	10	10	9	96
20	10	10	10	10	10	100
23	10	9	10	10	9	96
24	10	7	8	9	9	86
25	10	10	9	10	10	98

Additional analysis of performance on individual sentences for neurotypical participants revealed an increase of errors on two sentences pertaining to the angry emotion, one from sad, and one from neutral. The most errors for one sentence equated 11 (n = 38%) made while viewing the sentence “Quiet, this is a library.” The second most errors for one sentence equated 6 (n = 21%) made while viewing the sentence “Do not push your luck”. Analysis of performance on individual sentences for TBI participants revealed an increase of errors on four sentences pertaining to the angry emotion, one from sad, and one from fear. The most errors for one sentence equated six (n = 60%) made while viewing each of the following sentences “Quiet, this is a library”, “Do not waste my time”, and “Do not push your luck.” The second most errors for one sentence equated 5 (n = 50%) made while viewing each of the following sentences “It’s about to explode”, “I can hear footsteps in the night”, “You over-charged me for that.”

In a comparison between performances of neurotypical and TBI participants with regard to error pattern, nuerotypical participants demonstrated a condensed error pattern whereas the TBI subjects demonstrated an expansive error pattern; however, both groups demonstrated increased errors on two of the same sentences pertaining to the angry emotion. Thirteen out of 50 sentences did not receive an error by the TBI participants in contrast with 26 out of 50 sentences that did not receive an error by the nuerotypical participants. Eight of these did not receive any error by either group. (See Table 6).

Table 6. Distribution of errors for each item stimuli

NUEROTYPICAL PARTICIPANTS	Total Errors	TBI PARTICIPANTS	Total Errors
Quiet, this is a library	11	Do not push your luck.	6
Do not push your luck	6	Quiet, this is a library.	6
Stop what you're doing and listen to me	3	Do not waste my time.	6
Our body is made of water	3	You over-charged me for that.	5
This scene makes him feel blue	3	It’s about to explode.	5
Get out of my room	2	I can hear footsteps in the night.	5
You over-charged me for that	2	He has a knife.	4
I can't see the bear but I can hear it	2	Run for your life.	4
Digital clocks are common	2	I smell gas leaking from the stove.	4
He stands on the deck	2	I’m sick of you being late.	3
Lots of bins are in the room	2	Lots of bins are in the room.	3
I can hear footsteps in the night	2	This scene makes him feel blue.	3
Do not waste my time	1	This is a sad moment.	3
This song makes me cry	1	I hear a sharp scream from behind.	3
Containers have a blue lid	1	The fire is spreading to the gas pipe.	3
This is a garbage can	1	The weather is depressing.	2
Grey clouds make me feel gloomy	1	I am very angry.	2
I am so lonely	1	Get out of my room.	2
My best friend is moving away	1	This is a garbage can.	2
This is my favorite part	1	This song makes me cry.	2
My pet died today	1	Stop what you’re doing and listen to me.	2
This is infuriating	1	I am so lonely.	2
I smell gas leaking from the stove	1	Gray clouds make me feel gloomy.	2
I'm going to a funeral	1	Go to hell.	1
Look out there’s a car coming.	0	This is infuriating.	1
It’s about to explode.	0	I can’t see the bear but I can hear it.	1
I am very angry.	0	My pet died today.	1
Go to hell.	0	Watch out for that tiger.	1
This is a sad moment.	0	He stands on the deck.	1
Watch out for that tiger.	0	My best friend is moving away.	1
Run for your life	0	I’ve been crying all day.	1
Red pipes are metallic.	0	It’s a beautiful day outside.	1
This food tastes very good.	0	Look out there’s a car coming.	1
It’s a beautiful day outside.	0	This food tastes very good.	1
He has a knife.	0	Red pipes are metallic.	1
Four drawers are in the cabinet.	0	Four drawers are in the cabinet.	1
I’ve been crying all day.	0	A bag is in the room.	1
The weather is depressing.	0	I’m going to a funeral.	0
The fire is spreading to the gas pipe	0	This is my favourite part.	0
I hear a sharp scream from behind.	0	Our body is made of water.	0
I’m sick of you being late.	0	Containers have a blue lid.	0
A bag is in the room.	0	Digital clocks are common.	0
Congratulations, you’re hired.	0	I feel wonderful today.	0
I won an award.	0	Great, you got first place.	0
Good job, the crowd loved you.	0	Good job, the crowd loved you.	0
I feel wonderful today.	0	I won an award.	0
I got promoted in my job.	0	I see a rug on the floor.	0

Table 6 (continued)

This is the happiest day of my life.	0	This is the happiest day of my life.	0
Great, you got first place.	0	Congratulations, you're hired.	0
I see a rug on the floor.	0	I got promoted in my job.	0

Three participants with TBI did not respond within the given time constraints of stimuli presentation. These errors were recorded as a "no response" and were scored as an error. These responses were scored as an error because it is believed that the participant did not know the appropriate answer and thus could not respond correctly even if given more time to respond. The total number of "no response" errors was 5. Additionally, one participant with TBI began the viewing the practice items of the task but stated that they did not understand the task. The task was then stopped, the participant was re-oriented to the task, and the participant began viewing the task from the beginning.

DISCUSSION

This study examined if there was a significant difference in recognition of emotionally loaded lexical stimuli between individuals with traumatic brain injury (TBI) and individuals without brain damage (NBD) with regard to total error. Based on previous research by Green et al., 2004; Jackson & Moffat, 1987; Milders et al., 2003; Prigatano & Pribram, 1982; Spell & Frank, 2000; Marquardt et al., 2001; McDonald & Pearce, 1996; McDonald et al., 2003; McDonald & Flanagan, 2004, McDonald & Saunders, 2005; Borod et al., 1985; and Borod et al., 1992, it was predicted that individuals with brain injury would make more total errors than non-brain injured individuals. The results from this study concluded that the neurotypical participants produced significantly fewer errors than the TBI participants on the stimulus sentences in all five affective categories. Findings from the current study support previous research which states that individuals with brain injury demonstrate difficulty with emotion recognition in the facial, prosodic, and lexical processing channels. Decreases in performance on linguistic tasks of emotion recognition for individuals with brain injury as compared to neurotypical individuals are potentially due to decreases in processing speed, deficits in working memory, a failure to appreciate emotional implications of linguistic expression, or a failure to make inferences using theory of mind (Borod et al., 1992; McAllister et al., 2001; Shamay-Tsoory, Tomer, & Berger, 2003). A decrease in speed of processing or a deficit in working memory would prevent the participant from efficiently storing and interpreting the linguistic information in order to respond correctly (McAllister et al., 2001). Studies suggest that emotionally loaded words may be processed in the right hemisphere (Borod et al., 1992). Brain injuries resulting in diffuse damage to the right hemisphere would impede effective processing of emotion bearing words. Additionally, failure to read a statement and make inferences about the speaker's opinions, knowledge, and motivations may result in the inability to view a different perspective and thus interfere with the ability to generate the correct empathetic response (Shamay-Tsoory, Tomer, Berger, 2003).

Secondly, the current study examined if there was a significant difference in recognition of emotionally loaded lexical stimuli between individuals with traumatic brain injury (TBI) and individuals without brain damage (NBD) with regard to type of error. According to previous research based on Adolphs et al., 1996, it was predicted that both groups will demonstrate less errors for the happy affect. Additionally, it was predicted that individuals with brain injury would demonstrate the highest number of errors for the anger affect and the second highest number of errors for the neutral affect. Results from the current study confirmed significant differences between the sentence conditions reflecting better performance on the happy and neutral sentences compared to the angry sentences. Comparisons of conditions for the TBI participants found differences between happy and neutral sentences and angry and neutral sentences. Findings from the current study align with previous research which states that that patients with head injury were less able to identify negative emotions (i.e., angry, sad, sneaky) than positive emotions (i.e., happy, satisfied, welcoming) (Jackson and Moffat, 1987). Differences in performance amongst the task conditions potentially occurred due to punctuation uniformity utilized by all affective stimuli. Similar to changes in vocal pitch, punctuation specifies intonation in literature. An exclamation mark implies anger or fear, a question mark implies confusion, and a period implies neutrality. Without appropriate punctuation, it is possible that the participants did not recognize the emotional implication of the affective stimuli. Though not supportable by established research or numerical data, this theory garners support from observational commentary by participants in the nuertotypical group which, in sum, noted the lack of punctuation and consequential confusion. This theory warrants additional research to garner support and should be explored in future studies. Adolphs, Damasio, Tranel, Cooper, & Damasio (2000) provide an alternative justification, stating that diffuse axonal injury, a hallmark feature of TBI, severs neuronal connections critical for emotion perception. Such areas include the visual cortices, somatosensory-related cortices, and the amygdala. If these connections are not restored in the time post onset, it is like likely that diffuse axonal injury is the perpetrator for emotion perception deficits in these patients.

Finally, this study explored the sensitivity of the emotional assessment stimuli to identify sequelae of mild traumatic brain injury (TBI) developed by Ben-David et al. (2011). Item analyses exposed several stimulus items which neurotypical participants demonstrated increased errors on, stimulus items TBI participants demonstrated increased errors on, and stimulus items both groups of participants demonstrated increased errors on. Further analysis of data confirmed several stimulus items which neurotypical participants demonstrated decreased errors on, stimulus items TBI participants demonstrated decreased errors on, and stimulus items both groups of participants demonstrated decreased errors on. See Table 6 for complete distribution. Due to the high percentage of errors by both the neurotypical participants and the TBI participants on two of the sentence stimuli from the anger affect, it is suggested that these sentences are perhaps not valid test items for detecting impairments in emotion recognition in individuals with TBI. Furthermore, eight of the sentence stimuli did not receive an error by either participant group. Therefore, it is suggested that these eight sentences are perhaps not sensitive enough to detect impairments in emotion recognition in individuals with TBI. Differences in performance amongst the stimulus items potentially occurred due to ambiguous linguistic information, inappropriate affective label, or confusion resulting from inappropriate punctuation.

An alternative theory, though not supportable by established research or numerical data, states that differences in performance amongst the stimulus items potentially stems from ambiguity of perspective. Observational commentary provided by participants in the neurotypical group noted that several stimulus items convey an alternate emotion contingent upon the perspective of reader. A sentence read from the perspective of the speaker may convey anger while the same sentence read from the perspective of the listener may convey fear. This theory warrants additional research to garner support and should be explored in future studies.

LIMITATIONS

Limitations for the current study include a small sample size for both the TBI and neurotypical groups (n = 10, n = 29 respectively). A larger sample size would provide peak statistical power and thus make it easier to detect significant differences.

CONCLUSION

In summary, results of this study demonstrated that participants with TBI were significantly less accurate than participants with TBI in recognizing the affect of written linguistic stimuli. There were significant differences between the sentence conditions reflecting better performance on the happy and neutral sentences compared to the angry sentences. Comparisons of conditions for the TBI participants found differences between happy and neutral sentences and angry and neutral sentences. Additional analysis showed that both groups were significantly more accurate in recognizing sentences associated with a positive affect than sentences with a negative affect. Clinically, conclusions from this study are useful in determining which areas of linguistic emotion are more difficult for patients with TBI. Results from this study highlight the need for direct teaching of affective linguistic stimuli during treatment. These findings can benefit clinicians in determining which emotions to target first during treatment. Future research should examine a larger number of participants' with a broader range of cognitive/communication levels and educational backgrounds to develop a more complete synopsis of how these variables interact. Future research should continue to examine the interaction between affective linguistic stimuli and alexithymia while controlling for matched subjects. Further research is needed to develop sound neuropsychological assessment tools for individuals after TBI in order to examine deficits in emotion recognition for linguistic stimuli.

APPENDICES

Appendix A: Task Stimuli

Angry
Do not push your luck.
I'm sick of you being late.
Do not waste my time.
Quiet, this is a library.
Get out of my room.
Stop what you're doing and listen to me.
Go to hell.
This is infuriating.
I am very angry.
You over-charged me for that.

Fear
He has a knife.
It's about to explode.
I can hear footsteps in the night.
Look out there's a car coming.
I can't see the bear but I can hear it.
Run for your life.
I hear a sharp scream from behind.
The fire is spreading to the gas pipe.
I smell gas leaking from the stove.
Watch out for that tiger.

Happiness
Congratulations, you're hired.
I won an award.
Good job, the crowd loved you.
It's a beautiful day outside.
Great, you got first place.
This food tastes very good.
I feel wonderful today.
This is my favourite part.
I got promoted in my job.
This is the happiest day of my life.

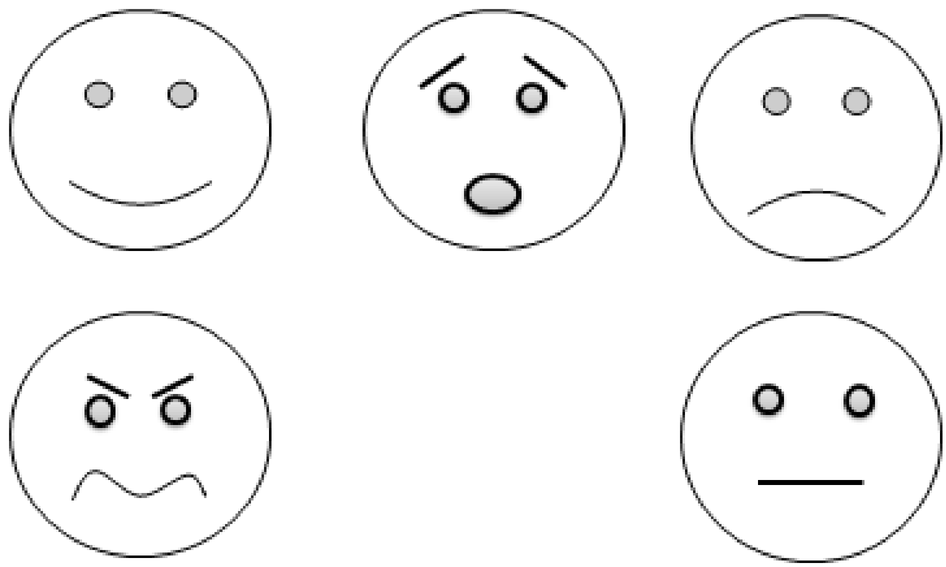
Sad
Gray clouds make me feel gloomy.
My pet died today.
I am so lonely.
The weather is depressing.
I'm going to a funeral.
This is a sad moment.
I've been crying all day.
This scene makes him feel blue.
My best friend is moving away.
This song makes me cry.

Neutral
A bag is in the room.
I see a rug on the floor.
Containers have a blue lid.
Lots of bins are in the room.
Digital clocks are common.
Our body is made of water.
Four drawers are in the cabinet.
Red pipes are metallic.
He stands on the deck.
This is a garbage can.

Appendix B: Practice Stimuli

1. I am graduating today.
2. No one sat beside me at lunch
3. Something is creeping up my leg.
4. This is not your concern.
5. My spoon is on the table.

Appendix C: Response Sheet



REFERENCES

Adamovich, B., & Henderson, J. (1992). Scales of cognitive ability for traumatic brain injury. *Itasca, IL: Riverside Publishing Company*.

Adams, J.H., Doyle, D., Ford, I., Graham, D.I., McGee, M., & McLellan, D.R. (1989). Brain damage in fatal non-missile head injury in relation to age and type of injury. *Scottish Medical Journal*, *34*(1), 399– 401.

Adams, J.H., Doyle, D., Graham, D.I., Lawrence, A.E., McLellan, D.R., Gennarelli, T.A., Pastuszko, M., & Sakamoto, T. (1985). The contusion index: A reappraisal in human and experimental non-missile head injury. *Neuropathology and Applied Neurobiology*, *11*(4), 299–308.

Adolphs, R. (2002). Neural systems for recognizing emotion. *Current Opinion in Neurobiology*, *12*(2), 169–177.

Adolphs, R., Damasio, H., Tranel, D., & Damasio, A.R. (1996). Cortical systems for the recognition of emotion in facial expressions. *Journal of Neuroscience*, *16*(23), 7678–7687.

Adolphs, R., Damasio, H., Tranel, D., Cooper, G., & Damasio, A.R. (2000).A role for the somatosensory cortices in the visual recognition of emotions as revealed by three dimensional lesion mapping. *Journal of Neuroscience*, *20*, 2683–2690.

Adolphs, R., Tranel, D., & Damasio, A.R. (2003). Dissociable neural systems for recognizing emotions. *Brain and Cognition*, *52*(1), 61– 69.

Beeman, M. (1993). Semantic processing in the right hemisphere may contribute to drawing inferences from discourse. *Brain and language*.

Ben-David B, Lieshout P, Leszcz T. (2011) A resource of validated affective and neutral sentences to assess identification of emotion in spoken language after a brain injury. *Brain Injury*, 25, 206-220.

Blonder, L. X., Bowers, D., & Heilman, K. M. (1991). The role of the right hemisphere in emotional communication. *Brain*, *114*(3), 1115-1127.

Borod, J. C., Andelman, F., Obler, L. K., Tweedy, J. R., & Welkowitz, J. (1992). Right hemisphere specialization for the identification of emotional words and sentences: Evidence from stroke patients. *Neuropsychologia*, *30*, 827– 844.

Borod, J. C., Koff, E., & White, B. (1983). Facial asymmetry in posed and spontaneous expressions of emotion. *Brain and Cognition*, *2*(2), 165-175.

Borod, J. C., Koff, E., Lorch, M. P., & Nicholas, M. (1985). Channels of emotional expression in patients with unilateral brain damage. *Archives of Neurology*, *42*(4), 345.

Braver, T. S., Cohen, J. D., Nystrom, L. E., Jonides, J., Smith, E. E., & Noll, D. C. (1997). A parametric study of prefrontal cortex involvement in human working memory. *Neuroimage*, *5*(1), 49-62.

Brooks, N., Campsie, L., Symington, C., Beattie, A., & Campsie, L. (1987). The effects of severe head injury on patient and relative within seven years of injury. *Journal of Head Trauma Rehabilitation*, *2*(3), 1–13.

Brookshire, R. H. (2007). Traumatic brain injury. *Brookshire RH, Introduction to neurogenic communication disorders*, 445-530.

Brownell, H. H., Potter, H. H., Bihrle, A. M., & Gardner, H. (1986). Inference deficits in right brain-damaged patients. *Brain and language*, *27*(2), 310-321.

Bruce A, Harman M, Turner M. (2007). Reactions to heard words: Varying emotional content and frequency of exposure. *Journal of General Psychology*, 134, 67-82.

Callahan, B., Ueda, K., Daisuke, S., Plamondon, A. (2011). Liberal bias mediates emotion recognition deficits in frontal traumatic brain injury. *Brain and Cognition*, 412-418.

Cohen, J. D., Perlstein, W. M., Braver, T. S., Nystrom, L. E., Noll, D. C., Jonides, J., & Smith, E. E. (1997). Temporal dynamics of brain activation during a working memory task.

Delis, D. C., Kramer, J. H., Kaplan, E., & Ober, B. A. (2000). CVLT-II. *The Psychological Corporation*.

Demaree, H. A., Everhart, D. E., Youngstrom, E. A., & Harrison, D. W. (2005). Brain lateralization of emotional processing: historical roots and a future incorporating "dominance". *Behavioral and Cognitive Neuroscience Reviews*, *4*(1), 3-20.

d'Esposito, M., Aguirre, G. K., Zarahn, E., Ballard, D., Shin, R. K., & Lease, J. (1998). Functional MRI studies of spatial and nonspatial working memory. *Cognitive Brain Research*, *7*(1), 1-13.

Dijkers MP. (2004). Quality of life after traumatic brain injury. A review of research approaches and findings. *Archives of Physical Medicine and Rehabilitation*. 85, 21-35.

Dimoska A, McDonald S, Pell M, Tate R, James C. (2010).Recognizing vocal expressions of emotion in patients with social skills deficits following traumatic brain injury. *Journal of the International Neuropsychological Society*.

Erhan, H., Borod, J.C., Tenke, C.E., & Bruder, G.E. (1998). Identification of emotion in a dichotic listening task: event-related brain potential and behavioral findings. Brain and Cognition, 37(2):286-307.

George, M. S., Mannes, S., & Hoffman, J. E. (1997). Individual differences in inference generation: An ERP analysis. *Journal of Cognitive Neuroscience*, *9*(6), 776-787.

Green, R. E., Turner, G. R., & Thompson, W. F. (2004). Deficits in facial emotion perception in adults with recent traumatic brain injury. *Neuropsychologia*, *42*(2), 133-141.

Hornak, J., Rolls, E.T., &Wade, D. (1996). Face and voice expression identification in patients with emotional and behavioural changes following ventral frontal lobe damage. *Neuropsychologia*, *34*(4), 247–261.

Jackson, H. F., & Moffat, N. J. (1987). Impaired emotional recognition following severe head injury. *Cortex: A Journal Devoted to the Study of the Nervous System and Behavior*.

Kendall, E., & Terry, D. (1996). Psychosocial adjustment following closed head injury: A model for understanding individual differences and predicting outcome. *Neuropsychological Rehabilitation*, 6, 101-132.

LaPointe, L. L. (1979). *Reading Comprehension Battery for Aphasia: Examiner's Manual, Stimulus Items, and Picture Plates*. Pro-Ed.

Larsen, JK, Brand, N, Bermond B, Hijman R. (2003). Cognitive and emotional characteristics of alexithymia. A review of neurobiological studies. *Journal of Psychosomatic Research*. 54, 533-541.

Levin, H.S. (1995). Neurobehavioral outcome of closed head injury: Implications for clinical trials. Journal of Neurotrauma, 12, 601-610.

Levin, H.S., High, W.M., Goethe, K.E., Sisson, R.A., Overall, J.E., Rhoades, H.M., Eisenberg, H.M., Kalisky, Z., & Gary, H.E. (1987). The neuro-behavioural rating scale: assessment of the behavioral sequalae of head injury by the clinician. *Journal of Neurology, Neurosurgery and Psychiatry, 50*, 183–193.

Levine, S. C., & Levy, J. (1986). Perceptual asymmetry for chimeric faces across the life span. *Brain and cognition*, *5*(3), 291-306.
Malia, K., Powell, G., & Torode, S. (1995) Personality and psychosocial function after brain injury. *Brain Injury*, 9, 697-712.
Marquardt, T.P., Rios-Brown, M., Richburg, T., Seibert, L.K., & Cannito, M.P. (2001). Comprehension and expression of affective sentences in traumatic brain injury. Aphasiology, 15 (10–11), 1091–1101.
Mcallister, T. W., Flashman, L. A., Sparling, M. B., & Saykin, A. J. (2004). Working memory deficits after traumatic brain injury: catecholaminergic mechanisms and prospects for treatment-a review. *Brain Injury*, *18*(4), 331-350.
McAllister, T. W., Sparling, M. B., Flashman, L. A., Guerin, S. J., Mamourian, A. C., & Saykin, A. J. (2001). Differential working memory load effects after mild traumatic brain injury. *Neuroimage*, *14*(5), 1004-1012.
McDonald, S, Saunders, J. (2005). Differentia impairment in recognition of emotion across different media in people with severe traumatic brain injury. *Journal of the International Neuropsychology Society*, 11, 392-399.
McDonald, S. & Pearce, S. (1996). Clinical insights into pragmatic language theory: The case of sarcasm. Brain and Language, 53, 81–104
McDonald, S., & Flanagan, S. (2004). Social perception deficits after traumatic brain injury: interaction between emotion recognition, mentalizing ability, and social communication. *Neuropsychology*, *18*(3), 572.
McDonald, S., Flanagan, S., Rollins, J., & Kinch, J. (2003). TASIT: A new clinical tool for assessing social perception after traumatic brain injury. *The Journal of head trauma rehabilitation*, *18*(3), 219.
McDowell, S., Whyte, J., & D'Esposito, M. (1997). Working memory impairments in traumatic brain injury: Evidence from a dual-task paradigm. *Neuropsychologia*.
Milders M, Fuchs S, Crawford JR. (2003). Neuropsychological impairments and changes in emotional and social behavior following severe traumatic brain injury. *Journal of Clinical and Experimental Neuropsychology*. 25, 157-172.
Myers, P.S. (1999*). Right Hemisphere Damage: Disorders of Communication and Cognition.* San Diego, CA: Singular.
Pang, D. (1989). Physics and pathology of closed head injury. In M. Lezak (Ed.), *Assessment of the behavioral consequences of head trauma* (pp. 1- 19). New York: A.R. Liss.
Phillips, M.L., Drevets, W.C., Rauch, S.L., & Lane, R. (2003). Neurobiology of emotion perception I: The neural basis of normal emotion perception. *Society of Biological Psychiatry*, *54*, 504–514.
Prigatano, G.P. & Pribram, K.H. (1982). Perception and memory of facial affect following brain injury. *Perceptual and Motor Skills*, *54*, 859–869.
Ross, E. D., & Mesulam, M. M. (1979). Dominant language functions of the right hemisphere? Prosody and emotional gesturing. *Archives of Neurology*, *36*(3), 144.
Russ J, Gur R, Bilker W. (2008). Validation of affective and neutral sentence content for prosodic testing. *Behavioral Research Methods*, 40, 935-939.
Sackeim, H.A., Gur, R.C., & Saucy, M.C. (1978). Emotions are expressed more intensely on the left side of the face. Science, 202(4366):434-6.

Shamay-Tsoory, S. G., Tomer, R., Berger, B. D., & Aharon-Peretz, J. (2003). Characterization of empathy deficits following prefrontal brain damage: the role of the right ventromedial prefrontal cortex. *Journal of cognitive neuroscience*, *15*(3), 324-337.

Smith, E. E., & Jonides, J. (1998). Neuroimaging analyses of human working memory. *Proceedings of the National Academy of Sciences*, *95*(20), 12061-12068.

Spell, L. A., & Frank, E. (2000). Recognition of nonverbal communication of affect following traumatic brain injury. *Journal of Nonverbal Behavior*, *24*(4), 285-300.

Tucker, D. M., & Frederick, S. L. (1989). Emotion and brain lateralization.

Wager, T. D., Phan, K. L., Liberzon, I., & Taylor, S. F. (2003). Valence, gender, and lateralization of functional brain anatomy in emotion: a meta-analysis of findings from neuroimaging. *Neuroimage*, *19*(3), 513-531.

Wechsler, A. F. (1973). The effect of organic brain disease on recall of emotionally charged versus neutral narrative texts. *Neurology*.

Whitney, P., Ritchie, B. G., & Clark, M. B. (1991). Working-memory capacity and the use of elaborative inferences in text comprehension. *Discourse Processes*, *14*(2), 133-145.

Ziegler J, Muneaux M, Grainger J. (2003) Neighborhood effects in auditory word recognition: Phonological competition and orthographic facilitation. *Journal of Memory and Language*, 48: 779-793.